Apocynum cannabinum interference in no-till *Glycine max*

Theodore M. Webster
Corresponding author. Department of Horticulture and Crop Science, Ohio Agricultural Research and Development Center, Ohio State University, Wooster, OH 44691. Current address: Crop Protection and Management Research Unit, USDA-ARS, Coastal Plain Experiment Station, Tifton, GA 31794-0748; twebster@tifton.cpes.peachnet.edu

John Cardina
Department of Horticulture and Crop Science, Ohio Agricultural Research and Development Center, Ohio State University, Wooster, OH 44691

Samuel J. Woods
Agricultural Technical Institute, Ohio State University, Wooster, OH 44691.

Field studies were conducted in three site-years to measure no-till *Glycine max* yield loss in relation to *Apocynum cannabinum* vegetative shoot density. *Apocynum cannabinum* densities of 28 to 40 shoots m^{-2} reduced predicted *G. max* yield 58 to 75% and 62 to 94% with the rectangular hyperbolic and linear regression models, respectively. Differences between locations were attributed to rainfall and temperatures, with delayed *G. max* canopy closure and higher yield loss where soil moisture remained high and temperatures were relatively cool. Application of these predictive *G. max* yield loss equations to field populations of *A. cannabinum* showed that between 19 and 36% and 20 and 29% *G. max* yield loss could be expected from within *A. cannabinum* patches for the rectangular hyperbolic and linear regression models, respectively. The rectangular hyperbolic regression model appeared to describe the relation between *G. max* yield loss and *A. cannabinum* density accurately; however, the model appeared to be dominated by the initial linear phase. This may indicate a lack of high levels of intraspecific competition among *A. cannabinum* shoots. The results of this study indicate that there is a strong linear relation between *G. max* yield loss and *A. cannabinum* shoot density. We conclude that the biological basis for the use of the rectangular hyperbolic model for creeping perennial weeds is questionable.

Nomenclature: *Apocynum cannabinum* L. APCCA, hemp dogbane; *Glycine max* (L.) Merr., soybean.

Key words: Competition, perennial weed, yield loss, APCCA.

Apocynum cannabinum (hemp dogbane) is a native creeping perennial weed distributed throughout North America. This weed has invaded *Zea mays* L. (corn) and *Glycine max* (soybean) fields becoming the second most troublesome perennial broadleaf weed in *Z. mays*–*G. max* rotations in Ohio (Loux and Berry 1991). A survey of Nebraska conducted in 1979 indicated that *A. cannabinum* infested up to 24% of *Z. mays* and 42% of *G. max* hectares (Schultz and Burnside 1979). In 1997, *A. cannabinum* was ranked as the seventh most troublesome species in Missouri and Virginia in *Z. mays* production, a distinction it did not have in 1974 (Buchanan 1974; Dowler 1997; Webster and Coble 1997). Increases in perennial weeds like *A. cannabinum* have been attributed to a combination of reduced tillage, reduced rates of triazine herbicides, and the reliance on herbicides with a low efficacy against perennials (Buhler 1995; Loux and Berry 1991; Triplett and Lytle 1972). Because of its phenology and herbicide tolerance, *A. cannabinum* will likely continue to increase in importance as a problem weed in reduced tillage fields (Doll 1995, 1997; Webster and Cardina 1999).

Apocynum cannabinum growing in competition with most agronomic crops does not produce many viable seeds (Schultz and Burnside 1979) and primarily reproduces vegetatively (Gerhards et al. 1997). Therefore, *A. cannabinum* infestations tend to be clumped or patchy in reduced tillage and no-till fields. A patch can contain interconnected rootstocks originating from a single seedling plant (Frazier 1944). Due to longevity of woody, creeping rootstocks, *A. cannabinum* patches are a persistent problem, with increasing potential for crop competition as patches expand over time.

The effect of *A. cannabinum* on crop yields has been studied in conventionally tilled fields in Nebraska, where

Sorghum bicolor (L.) Moench. (grain sorghum) yield was reduced 37 to 45% by *A. cannabinum* densities from 6.3 to 7.7 shoots m^{-2} (Schultz and Burnside 1979). An *A. cannabinum* density of 6.3 shoots m^{-2} reduced *G. max* yield 41%, but a similar density reduced *Z. mays* yield only 8 to 10% (Schultz and Burnside 1979). However, there are no studies relating crop yield to the range of densities of *A. cannabinum* that normally appear in patches in no-till *G. max* fields.

Functional relationships describing weed–crop competition have been developed mostly for annual weeds (Cousens 1985) with less attention to perennials. Because of important anatomical and physiological differences between annual and perennial weeds (e.g., carbohydrate supply) (McIntyre 1990), it is uncertain that yield–density relationships that describe crop competition with annual weeds will apply also to perennials. The patch-forming growth habit of *A. cannabinum* is representative of many creeping perennial weeds of reduced tillage crops. Therefore, understanding how crop yields are affected by *A. cannabinum* shoot density at the whole-patch level could help develop principles of competition for perennial weeds with creeping root systems.

The objective of this research was to determine the relationship between *A. cannabinum* shoot density and yield loss in no-till *G. max* and to apply this information to describe potential yield losses in naturally occurring patches of *A. cannabinum* in grower's fields.

Materials and Methods

Field studies were conducted in 1996 and 1997 at the Ohio State University Agricultural Technical Institute (ATI) in Wooster, OH, and in 1997 at the Graham farm near

Wooster, OH. Studies were established in both fields in areas with natural populations of *A. cannabinum* in *G. max.* The soil type at ATI was a well-drained Wooster silt loam (Typic Fragiudalf) and that at the Graham farm was a somewhat poorly drained Canfield silt loam (Aeric Ochraqualf). *Glycine max* was drilled in rows 18 cm apart in early May 1996 or late April 1997 at a population of 395,000 seeds ha^{-1}. Both sites had a history of no-till *Z. mays–G. max* rotations; the Graham farm had been in this rotation since 1985 and the ATI site since 1990. Fields received an application of 0.4 kg ae ha^{-1} glyphosate 10 d before planting and prior to emergence of any *A. cannabinum* shoots. Annual grass and small-seeded broadleaf weeds were controlled using 2.6 kg ai ha^{-1} metolachlor plus 0.07 kg ai ha^{-1} flumetsulam applied preemergence, followed by 0.14 kg ai ha^{-1} clethodim postemergence.

A completely randomized design was used based on methods used to study crop interference with other perennial weeds (Donald and Khan 1992; Patterson et al. 1980; Yenish et al. 1997). Quadrat samples were used to determine the shoot density and yield loss relationship. Quadrats (0.5 by 0.5 m) were located after crop and *A. cannabinum* emergence, to obtain a range of *A. cannabinum* densities from 0 to 40 shoots m^{-2}. Each quadrat contained three rows of *G. max.* We use the term shoots instead of plants because it was impossible to determine interconnections among roots of neighboring shoots (Frazier 1944) and because few *A. cannabinum* seedlings were observed during the study (< 5% of the shoots were from seedlings). The lack of *A. cannabinum* seedlings could be a function of the preemergence herbicides, especially metolachlor, which may have activity on seedling *A. cannabinum.* Data were collected from 150 to 300 quadrats in each field. *Apocynum cannabinum* shoot densities were recorded periodically throughout the growing season, and *G. max* was harvested at maturity from within the quadrats. *Glycine max* seed yields were corrected to 13% moisture prior to data analysis. The average yield from weed-free control quadrats was used to calculate relative *G. max* yield losses in weedy quadrats. Weed-free quadrats were scattered throughout the experimental area between, and no less than 3 m from, patches of *A. cannabinum.* Yields from weed-free quadrats averaged 2,376, 3,590, and 2,950 kg ha^{-1} at ATI (1996), ATI (1997), and Graham, respectively.

In another part of the field at ATI, 6 and 12 *A. cannabinum* patches ranging in size from 22 to 350 m^2 were identified in 1997 and 1998, respectively. The patch borders were measured with a global positioning system with real-time differential correction, using the methods described by Webster and Cardina (1997). Grid samples were used to determine the percentage of area in each patch that contained various densities of *A. cannabinum* shoots. Grid samples were obtained by dividing an entire patch into 1-m^2 grids and counting the number of *A. cannabinum* shoots per grid. These data were used along with the *G. max* yield loss estimates from the quadrat samples to estimate yield loss within an *A. cannabinum* patch.

Glycine max yield loss data were regressed against *A. cannabinum* density, and both a linear model and a rectangular hyperbolic model, described by Cousens (1985), were fit using a least squares iterative procedure. Data for locations are presented separately because of differences among locations. Due to similarity of density distribution within patch-
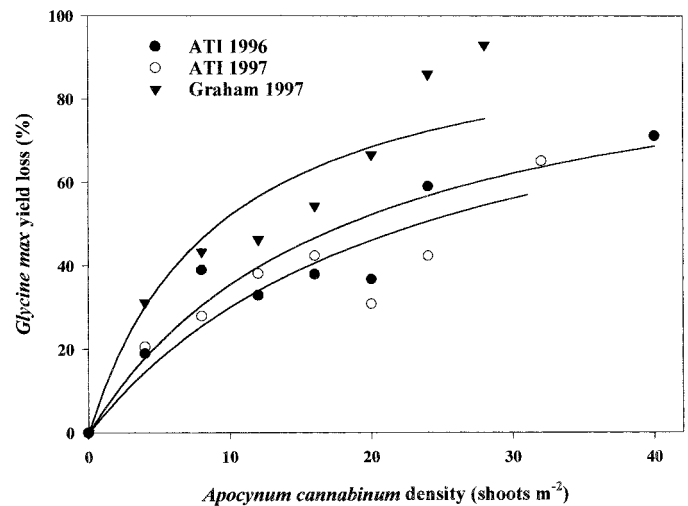

FIGURE 1. Rectangular hyperbolic regression of *Glycine max* yield loss on *Apocynum cannabinum* shoot density in 1996 and 1997 at the Ohio State University Agricultural Technical Institute Farm (ATI) and at the Graham Farm in 1997. The regression equations for the ATI farm were: ($y = (5.5x)/ (1 + (5.5x)/100)$), $r^2 = 0.80$ in 1996; ($y = (4.3x)/(1 + (4.3x)/100)$), $r^2 = 0.81$ in 1997. The regression equation for the Graham farm was ($y = (10.9x)/(1 + (10.9x)/100)$), $r^2 = 0.70$ in 1997.

es in a field, estimated yield losses are reported for the average patch density.

Results and Discussion

The relationship between *A. cannabinum* shoot density and *G. max* yield loss was described by a rectangular hyperbolic function with r^2 values from 0.70 to 0.81. There were differences in predicted *G. max* yield loss at the maximum *A. cannabinum* density recorded in each field (Figure 1). The predicted maximum yield loss in 1996 at ATI approached 69% with a density of 40 *A. cannabinum* shoots m^{-2}. Similarly, the highest predicted *G. max* yield loss in this same field in 1997 was 58% with 32 *A. cannabinum* shoots m^{-2}. However, at the Graham field in 1997, a predicted *G. max* yield loss of 75% was recorded with a density of 28 *A. cannabinum* shoots m^{-2}. The differences between fields may be related to a number of factors. The Graham field is located at a relatively low point in the county in a floodplain, about 100 m lower in elevation than the ATI field. Heavy rains were experienced at both locations in 1997; however, because of poor drainage, the Graham field had excess moisture in mid-June. Although this field had tile drainage and *G. max* yields in the weed-free areas were similar to those at ATI, *G. max* plant growth was not as robust as that at ATI. The *G. max* at Graham were about 21 to 25 d behind ATI in forming a closed canopy. Also, *A. cannabinum* is frequently found growing in wet soils, river banks, and seasonally wet meadows and marshes (Henn 1998; Voss 1996). Therefore, we suspect that the excess soil moisture at Graham may have altered the competitive balance, allowing *A. cannabinum* to tolerate the wet growing conditions, while *G. max* experienced water stress.

The rectangular hyperbolic equation has been used to describe the relation between weed density and crop yield loss for interference studies (Cousens 1985). The regression curves describing the relation between *A. cannabinum* shoot density and *G. max* yield loss had a strong linear phase
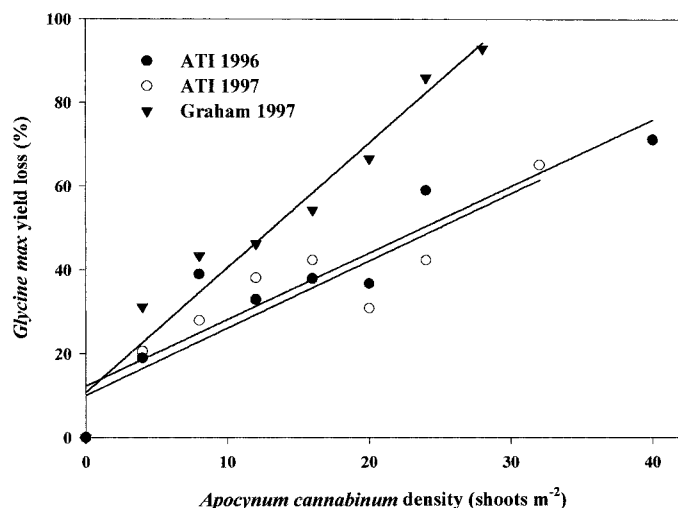
FIGURE 2. Linear regression of *Glycine max* yield loss on *Apocynum cannabinum* shoot density in 1996 and 1997 at the Ohio State University Agricultural Technical Institute Farm (ATI) and at the Graham Farm in 1997. The regression equations for the ATI farm were: ($y = 1.59x + 12.3$), $r^2 = 0.85$ in 1996; ($y = 1.61x + 10.1$), $r^2 = 0.82$. The regression equation for the Graham farm was ($y = 2.98x + 10.8$), $r^2 = 0.94$ in 1997.

specific and intraspecific (weed–weed) competition. The initial linear component of the model persisted over the upper range of *A. cannabinum* densities found in the patches. Although this model appears to describe the data at the lower weed densities, the model does not seem to be as accurate at the highest weed densities. This may suggest that *A. cannabinum* shoot densities were never high enough in naturally occurring patches to cause significant intraspecific competition among shoots. Alternatively, a linear model appeared to improve the accuracy of the predicted *G. max* yield loss at high densities; however, the regression did not go through the origin and thus may not have accurately predicted yield loss at lower *A. cannabinum* densities (Figure 2). Similar results were reported for *Asclepias syriaca* L. (common milkweed) in *Triticum aestivum* L. (hard red spring wheat) (Yenish et al. 1997). Within a patch, the density of interconnected shoots attached to a single *A. cannabinum* plant is probably regulated by bud dormancy so that an optimum density is achieved where individual shoots compete. Lovett Doust (1981) proposed two classifications for clonal perennials, phalanx strategists and guerrilla strategists. A plant with phalanx strategist growth habit would exhibit a consolidated radial spread and consist of plants with high interclonal contact that would exclude all other plant species. Plants that grow as guerrilla strategists have widely spaced ramets that maximize interspecific plant contact, resulting in rapid expansion into new territory. The apparent lack of intraspecific interference and relatively wide spacing (i.e., low density) of emerged shoots are adaptive

without a clear asymptote (Figure 1). The rectangular hyperbolic model is typically used to describe weed–crop interference because it consists of two linear phases: one describes interspecific (weed–crop) competition at low weed densities, and the other, at high densities, describes inter-

TABLE 1. Predicted *Glycine max* yield loss for average shoot densities within *Apocynum cannabinum* patches using both the linear and rectangular hyperbolic models.

		Predicted *G. max* yield loss					
A. cannabinum density	Patch area[a]	Rectangular hyperbole[b]			Linear[c]		
		ATI 1996	ATI 1997	Graham 1997	ATI 1996	ATI 1997	Graham 1997
shoots m^{-2}	%	%					
1	10.6	0.55	0.44	1.04	1.47	1.24	1.46
2	10.4	1.03	0.82	1.86	1.61	1.39	1.74
3	10.1	1.43	1.15	2.49	1.72	1.51	1.99
4	9.8	1.77	1.44	2.98	1.83	1.62	2.23
5	9.3	2.01	1.65	3.28	1.88	1.69	2.39
6	8.7	2.16	1.78	3.44	1.90	1.72	2.50
7	7.9	2.20	1.83	3.42	1.85	1.69	2.50
8	7.0	2.14	1.79	3.26	1.75	1.61	2.42
9	5.9	1.95	1.65	2.92	1.57	1.45	2.22
10	4.9	1.74	1.47	2.56	1.38	1.28	1.99
11	3.9	1.47	1.25	2.13	1.16	1.08	1.70
12	3.0	1.19	1.02	1.70	0.94	0.88	1.40
13	2.2	0.92	0.79	1.29	0.73	0.68	1.09
14	1.6	0.70	0.60	0.97	0.55	0.52	0.84
15	1.1	0.50	0.43	0.68	0.40	0.38	0.61
16	0.8	0.37	0.33	0.51	0.30	0.29	0.47
17	0.6	0.29	0.25	0.39	0.24	0.22	0.37
18	0.4	0.20	0.17	0.26	0.16	0.16	0.26
19	0.3	0.15	0.13	0.20	0.13	0.12	0.20
20	0.2	0.10	0.09	0.14	0.09	0.08	0.14
21	0.1	0.05	0.05	0.07	0.05	0.04	0.07
Total[d]	98.8	22.92	19.15	35.59	21.71	19.66	28.59

[a] The percent patch area for each *A. cannabinum* density was derived from the equation in Figure 3.
[b] The predicted *G. max* yield loss for each density was calculated using the rectangular hyperbolic regression models from Figure 1.
[c] The predicted *G. max* yield loss for each density was calculated using the linear regression models from Figure 2.
[d] The total *G. max* yield loss was calculated by summing the proportional yield loss from each *A. cannabinum* density.
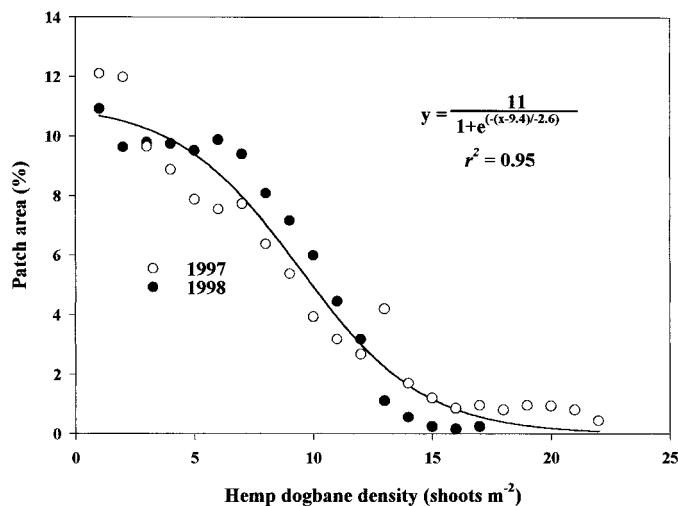
FIGURE 3. *Apocynum cannabinum* density distribution in natural patches of *A. cannabinum.*

The figure contains the equation:

$$y = \frac{11}{1+e^{(-(x-9.4)/-2.6)}}$$

$$r^2 = 0.95$$

strategies common to guerrilla strategists (Lovett Doust 1989) and may allow *A. cannabinum* to coexist with other plant species. Therefore, although there is a clear biological justification for using the rectangular hyperbolic model to describe annual weed interference in crops, it is unclear if this relation can be extended to creeping perennial weeds.

The relation between *A. cannabinum* patch area and shoot density was described by an inverted sigmoid function ($r^2 = 0.95$) (Figure 3). Within patches, approximately 50% of the area contained five or fewer *A. cannabinum* shoots m^{-2}. This indicates that although high densities of *A. cannabinum* caused substantial *G. max* yield loss, only a small proportion of the area of a patch contained high shoot densities. Approximately 94% of the patch area had 15 or fewer shoots m^{-2}, which was at most half of the maximum *A. cannabinum* density in the interference studies (Figures 1 and 2).

Application of the predicted *G. max* yield loss data to the density distribution within these patches provides expected crop yield losses for entire patches (Table 1). For example, a density of 1 *A. cannabinum* shoot m^{-2} was found in 10.6% of the average patch area (Table 1), and this density resulted in a predicted yield loss of 4 to 10% and 12 to 14% using the rectangular hyperbolic and linear regression models, respectively (Figures 1 and 2). Therefore, through multiplication of these values, we can determine that this *A. cannabinum* density reduced *G. max* yield 0.44 to 1.04% and 1.24 to 1.47% in the average patch (Table 1). At the relatively high density of 20 shoots m^{-2}, the predicted yield loss ranged from 45 to 70% and 42 to 70% for the rectangular hyperbolic and linear regression models, respectively (Figures 1 and 2). However, this density only occurred in 0.2% of the patch area; thus, the proportional yield loss from this density in an average patch was between 0.09 and 0.14% (Table 1). Integrating the yield loss in the average *A. cannabinum* patch provided an estimated 19 to 36% and 20 to 29% *G. max* yield loss due to *A. cannabinum,* using the rectangular hyperbolic and linear models, respectively. To determine whether this yield loss per patch is above an economic threshold, a grower would have to consider the value of the yield gained by controlling *A. cannabinum,* the cost and chances of successful control, and potential crop

damage due to herbicide injury and driving a tractor over narrow-row *G. max.* This decision should also include losses to subsequent crops if control measures are not taken, but there is little information available on the rate or extent and patch spread that would be necessary to make this decision.

Acknowledgments

Literature Cited

Buchanan, G. A. 1974. Weed survey—southern states. South. Weed Sci. Soc. Res. Rep. 27:215–249.

Buhler, D. D. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean in the central USA. Crop Sci. 35:1247–1258.

Cousens, R. 1985. A simple model relating yield loss to weed density. Ann. Appl. Biol. 107:239–252.

Doll, J. D. 1995. Hemp dogbane growth and control in corn and soybean. North Cent. Weed Sci. Soc. Proc. 50:79- 85.

Doll, J. D. 1997. Hemp dogbane (*Apocynum cannabinum* L.) management in corn and glyphosate resistant soybeans. Weed Sci. Soc. Am. Abstr. 37:90.

Donald, W. W. and M. Khan. 1992. Yield loss assessment for spring wheat (*Triticum aestivum*) infested with Canada thistle (*Cirsium arvense*). Weed Sci. 40:590–598.

Dowler, C. C. 1997. Weed survey—southern states—grass crop subsection. Proc. South. Weed Sci. Soc. 50:227–246.

Frazier, J. C. 1944. Nature and rate of development of root system of *Apocynum cannabinum.* Bot. Gaz. 105:463–470.

Gerhards, R., D. Y. Wyse-Pester, D. Mortensen, and G. A. Johnson. 1997. Characterizing spatial stability of weed populations using interpolated maps. Weed Sci. 45:108–119.

Henn, R. L. 1998. Wildflowers of Ohio. Bloomington and Indianapolis, IN: Indiana University Press, pp. 38–39.

Loux, M. M. and M. A. Berry. 1991. Use of a grower survey for estimating weed problems. Weed Technol. 5:460–466.

Lovett Doust, L. 1981. Population dynamics and local specialization in a clonal perennial (*Ranunculus repens*) I. The dynamics of ramets in contrasting habitats. J. Ecol. 69:743–755.

Lovett Doust, L. 1989. Infiltration invasion—or dispersal and fate? Funct. Ecol. 3:379–382.

McIntyre, G. I. 1990. The correlative inhibition of bud growth in perennial weeds: a nutritional perspective. Rev. Weed Sci. 5:27–48.

Patterson, M. G., G. A. Buchanan, J. E. Street, and R. H. Crowley. 1980. Yellow nutsedge (*Cyperus esculentus*) competition with cotton (*Gossypium hirsutum*). Weed Sci. 28:327–329.

Schultz, M. E. and O. C. Burnside. 1979. Distribution, competition, and phenology of hemp dogbane (*Apocynum cannabinum*) in Nebraska. Weed Sci. 27:565–570.

Triplett, G. B. and G. D. Lytle. 1972. Control and ecology of weeds in continuous corn grown without tillage. Weed Sci. 20:453–457.

Voss, E. G. 1996. Michigan Flora. Volume 3. Dicots. Cranbook Institute Science Bull. 61 Ann Arbor, MI: Edward Brothers. 622 p.

Webster, T. M. and J. Cardina. 1997. Accuracy of a global positioning system (GPS) for weed mapping. Weed Technol. 11:782–786.

Webster, T. M. and J. Cardina. 1999. *Apocynum cannabinum* seed germination and vegetative shoot emergence. Weed Sci. 47:524–528.

Webster, T. M. and H. D. Coble. 1997. Changes in the weed species composition of the southern United States: 1974 to 1995. Weed Technol. 11:308–317.

Yenish, J. P., B. R. Durgan, D. W. Miller, and D. L. Wyse. 1997. Wheat (*Triticum aestivum*) yield reduction from common milkweed (*Asclepias syriaca*) competition. Weed Sci. 45:127–131.